International Journal of Computer Applications (0975 – 8887)
Volume 66– No.9, March 2013

Merits and Demerits of Existing Energy Efficient Data Gathering Techniques for Wireless Sensor Networks

Bhat Geetalaxmi Jayram
Associate Professor,
Department of Information Science and Engineering,
National Institute of Engineering, Mysore,
Karnataka, India.

D. V. Ashoka, PhD.
Professor and Head,
Department of Information Science and Engineering,
JSS Academy of Technical Education, Banglore,
Karnataka, India.

ABSTRACT
Wireless sensor networks (WSN) are self organized, low cost and low power utilizing network which senses, calculates and communicates the data. The data collection at sensor nodes consumes a lot of energy and sensor nodes have limited energy. Hence most of the data-gathering schemes aim to prolong the lifetime of WSNs by saving power consumption and optimized data transmission. This paper makes an extensive survey of various data gathering techniques in the WSN. The survey is done by dividing the data gathering techniques as static and mobile based on the mobility of the nodes. The data gathering techniques are analyzed in terms of energy conservation, reliability, network life time, cost, data latency and various other parameters. We present a comparison of those existing data gathering techniques along with their advantages and issues.

Index Terms
Consumption, Efficiency, Latency, Forwarding interruption, Gathering.

1. INTRODUCTION
Wireless sensor network is an emerging technology gaining immense attention from the research community recently. Usually, sensor network is self-organizing ad-hoc system with large number of small and low-cost devices. It can monitor the physical environment, consequently collect information and then transmit the collected information to the sink node (also called as control center or base station) [1].

Each node in the wireless sensor network is equipped with sensors, microprocessors, memory, wireless transceiver, and battery [2]. Each sensor node contains one or more sensing devices for monitoring the environment and gathering the data. The processor presented in the sensor node is used to process the gathered data and communicate with the hardware for transmitting the data to other local sensor nodes [3]. The sensor network has wide range of applications in several fields such as healthcare, environmental monitoring, smart homes, military applications etc. It is most suitable for application including structural monitoring, health monitoring, environmental monitoring etc, since it has monitoring abilities and autonomous operation [4].

In sensor networks, the process of sampling the information and transmitting it to central base stations is called data gathering. The information received by base station will be further processed and analyzed [5]. In some data gathering applications such as object tracking and intrusion detection, the time sensitive data is required to be sent back to the station in a near real time manner. The applications like acoustic sensor networks, underwater or ocean sensor networks and environmental monitoring do not need real-time data transmission and access. It can be used in scientific applications by domain scientists to collect scientific data for further analysis [6].

There are three stages in data gathering process: the deployment stage, the control message dissemination stage and the data delivery stage. In the deployment stage, the network deployment issues of the sensing field can be addressed. In the control message dissemination stage, the network setup/management and/or collection command messages can be distributed between the base station and all sensor nodes. In this stage, distributing the messages to all the sensor nodes with low transmission costs and latencies is the challenging task. In the data delivery stage, the data gathering (data collection) process will be completed [7]. In the sensor network, the sensor nodes can generate distributed sites of data, and hens the sensor network is also called as data centric network. The minimization of the energy spent in the transmission of sensor data back to the sink is the key challenge. The data collection techniques are classified into two namely, static node based data collection and Mobile element based data collection [4].

1.1. Issues of Data Gathering
1) The sink is static node which acts as a gateway between the sensor network and users. The sensor nodes can send the sensing data to this sink node in a multi hop manner. The sensors near to the sink node become the bottleneck, because they should transmit the data of other nodes with more energy consumption [8].

2) In WSN, energy-efficiency is the major issue. The sensor network requires large number of sensor nodes to operate over a long time period, and hence the energy resources should be managed efficiently. As the data gathering process requires more energy, the designing of energy-efficient communication strategies and its implementation is essential [9].

3) The reduction in energy consumption and increasing the amount of generated data simultaneously is a big challenge while monitoring an environment. Hence the trade-off between energy consumption and environment observation accuracy is a conflicting goal to achieve. So it remains as a hot topic in wireless sensor networks.

4) In the delay sensitive applications, like battlefield monitoring, the delay between data generation and data processing should be reduced. This is the difficult task due to the distance between the nodes and the Sink. [10].

5) The important application of sensors, like military operation, requires additional requirements including reliability and real-time operation on sensors and ad-hoc networks. The nodes have only limited battery life. It is a great challenge for the real-time and reliability requirements. Hence efficient energy consumption techniques are required.

6) The sensor nodes gather data from the environment aggregates it in the intermediate nodes and transmits to the base station. Many issues arises due to operations with limited power in a wireless media; reliable communication, power efficiency and network survivability in the sensor nodes [11].

The limitations of WSN in real time data acquisition are the following:

1) Limited Memory and Storage Space: The data size plays a significant role in guaranteeing real time data acquisition as the sensor nodes are small devices and due to their limited storage spaces, memories and processors. For example, the aggregation of data needs sufficient memory space and processor. The delay may increase in case the process is executed by non-sufficient memory nodes.

2) Energy Limitation: The computation as well as the communication processes within a node consumes energy. The sensor capabilities of the sensor nodes are extremely affected by the energy limitation. The real-time data is transmitted using the optimal solutions. It consumes low communication power. Critical issue is the energy consumption in aggregation.

3) Environmental Limitations: Sensor nodes suffers many environmental difficulties like physical obstacles, node terminations, unpredictable errors. It avoids the functioning of nodes, or communication interferences

4) Communication Constraints: The real time communication schemes between nodes are provided through some preventive actions. The relevant subjects of communication constraints are:

- Unreliable communication

- Bandwidth limitation

- Frequent routing changes

- Channel error rate

5) Additional Limitations: Since WSNs are deployed for particular objectives, new constraints related to the specified area are emerged.

- Node mobility

- Intermittent connectivity

- Isolated subgroups

- Population density

The real time requirements are guaranteed considering all these constraints [11].

-- As the wireless channels are unstable, there is no guarantee for the reliability of data delivery from sensors to the sink. It causes data loss, energy waste and also decreases the amount of information collected by the sink and increases the total energy consumption by the sensors [12].

The main challenges in maximizing network utility in data-gathering WSNs are as mentioned below:

1) The path from any sensor to the sink is selected depending on the network topology and the benefit value of each operation.

2) The same path is shared by the different sensor for sending data to save energy. This causes link failures.

3) A number of sensors having data to send increase the complexity of the problem.

4)The delivery ratio for a path/link increases the retransmission as well as increases transmission delay and energy consumption [12].

This survey paper focuses on the data gathering and its issues in WSN. The major issues dealt in this survey are energy efficiency and the reliability issues of data gathering in the network. Many of the existing works based on data gathering is analyzed in terms of energy efficiency and reliability. The various data gathering techniques are analyzed and this analysis draws a conclusion for the effective energy utilization of the network during data gathering process.

2. RELATED WORKS

K. Ramanan and E. Baburaj [13] have outlined different critical issues in wireless sensor network. An extensive study of different issues associated with existing data gathering algorithms is done and here two key issues are focused. The issues focused on are network lifetime and saving energy of them. Since wireless sensor networks have great scope in the research field, to solve many open issues still researches are going on. Wireless sensor networks are at the time of this writing not yet ready for practical deployment because some of the underlying hardware problems with respect to the energy supply and miniaturization were not solved completely. The problems cannot be resolved in the near future also. In a Wireless sensor networks, more data can be collected by the sink(s) by prolonging the network lifetime. Hence the sink collects more data. The efficient usage of energy is crucial for the networks lifetime.

Mario Di Francesco et al [14] have extensively characterized data collection in Wireless Sensor Networks with Mobile Elements (WSN-MEs). WSNs with MEs are defined. A comprehensive taxonomy of their architectures is provided based on the role of the MEs. An overview of the data collection process is presented and the corresponding issues and challenges are identified. An extensive survey of the related literature is provided based on these issues. The underlying approaches and solutions are compared with the existing works with hints to open problems and future research directions. The data collection process is discussed in depth and its main challenges are highlighted. The analysis of each topic by a comparative survey of the approaches available in the literature is done.

Feng Wang and Jiangchuan Liu [7] have presented a survey on the recent advancements on tackling the challenges on the usage of WSNs for sensor data collection. The special features of sensor data collections in WSNs are highlighted by comparing with both wired sensor data collection networks and other applications of WSNs. The issues and prior solutions on sensor network deployment and data delivery protocols are discussed. The different approaches for control message dissemination are discussed. It acts as an indispensable component for network control and management. It can also greatly affect the overall performance of WSNs for sensor data collections.

Ramesh Rajagopalan and Pramod K. Varshney [15] have presented a comprehensive survey of data aggregation algorithms in wireless sensor networks. Most of the works focus on the optimization of important performance measures such as network lifetime, data latency, data accuracy and energy consumption. The three main focus areas of data aggregation algorithms are efficient organization, routing and data aggregation tree construction. The main features, the advantages and disadvantages of each data aggregation algorithm are described and also the special features of data aggregation such as security and source coding. They also highlighted the trade-offs between energy efficiency, data accuracy and latency. The development of an efficient routing mechanism for data aggregation is focused in most of the existing work. Even though the works on data aggregation technique looks promising, they have scope for future research. There is still much more to explore in the context of data aggregation combining the aspects of security, data latency and system lifetime. The relation between energy efficiency and system lifetime and its systematic study can be an avenue of future research.

3. SURVEY ON DATA GATHERING TECHNIQUES

There are two major types of data collection techniques:

-- Static nodes based data collection

-- Mobile elements based data collection [4].

There are many challenges for gathering data from mobile sensors. A Mobile Wireless Sensor Network (MWSN) is similar to a static Wireless Sensor Network (WSN) having traditional constraints like energy limitation, narrow bandwidth and limited computation ability [16]. The data gathering techniques are analyzed in terms of energy, cost and reliability.

3.1. Static Node Based Data Collection

Distributed Data Aggregation Protocol (DDAP)[1]

Distributed Data Aggregation Protocol (DDAP) is a self-organizing data aggregation protocol which randomly distributes the data aggregator roles among the sensor nodes in the network. It is simple and distributed and is without any central authority. The decision to handover the packets are taken by the nodes locally. The local aggregator nodes (ANs) are elected by the sensors from among themselves at any given time with a given probability. Aggregator Nodes are used to decrease the amount of packets sent. Hence the energy required for communication is reduced. The aggregator node's adaptivity is not taken into consideration. In future, more powerful adaptive DDAP can be proposed for efficient power saving.

Hybrid Clustering Based Data Aggregation Scheme [17]

Hybrid Clustering Based Data Aggregation Scheme can adaptively choose a suitable clustering technique based on the status of the network, increasing the efficiency of data aggregation. It is also efficient in energy consumption and successful data transmission ratio. The adaptive clustering based data aggregation method performs well in target detecting and environment tracking. It switches its aggregation scheme based on the status of the network; this ability keeps its performance to a high level. The best performance is shown with static targets by the dynamic clustering protocol. It becomes useless in the case of mobile targets. The static clustering method provides reliable performance in case of both static and mobile target, but its overall performance is only adequate. Each sensor node's average energy consumption in no aggregation, static aggregation, and dynamic aggregation are compared with the proposed scheme sensing static targets and mobile target. As the sensing range increases, the energy consumption of each algorithm also increases. It is because more sensor nodes are available to sense an event at the same time, generates more data packets with the increase in sensing range. In case of static targets, the dynamic clustering based data aggregation method shows the best performance compared to the static clustering based data aggregation. The latter has considerable overhead. It happens because the dynamic clustering method does not have to frequently generate clusters in the case of static target. Hence energy is saved. The aggregation methods are switched using the flooding technique in adaptive clustering based data aggregation protocol. Hence produces large amounts of overhead.

Optimal routing and data aggregation scheme [18]

The optimal routing and data aggregation scheme is used for the maximization of the network lifetime of sensor networks. The geometric routing is adopted as it determines the routing according to the nodal position. It allows the incorporation of different data correlation models without intervening with the underlying routing scheme. The problem focuses on the computation of optimal routing variables. Hence the network lifetime is maximized. The smoothing function is proposed to approximate the original max function by exploiting the special structure of the network as the maximum lifetime problem cannot be solved directly using the simple distributed methods. A distributed gradient algorithm is designed in accordance with the optimality of the smoothing function. It is achieved deriving the necessary and sufficient conditions. The reduction in data traffic and the network lifetime improvement can be achieved through the scheme. The optimal value convergence is done by the distributed algorithm efficiently. It does not consider the data aggregation of multiple sink nodes and for nodes with sleeping mode.

Power-graded data gathering (PODA) [19]

Power-graded data gathering (PODA) is a new data gathering mechanism. The output power is adjusted at the system level in order to tackle the hotspot problem in wireless sensor networks for gathering data in large areas. As the nodes are made far from the sink, it uses higher output power than those near the sink. Here all the nodes in the network consume energy evenly. Hence the energy efficiency is improved and the network lifetime is prolonged. The characteristics of the protocol are as follows:

1) Consumption of energy is even in the whole network.

2) The protocol is simple having low protocol cost, and easy implementation.

The PODA makes the fullest utilization of the output power of the RF chips which is dynamically adjustable to achieve energy balance in the whole network. The nodes near the sink adopt smaller communication radii whereas the nodes far from the sink use larger communication radii in this mechanism. The nodes near the sink transmit more data but the consumption of energy in transmitting a data packet is lower. The situation is reverse in the case of nodes far from sink. Hence a notably even energy consumption in the entire network, improved energy efficiency and prolonged the network lifetime are achieved. The implementation of PODA is easy having little protocol overhead. It also combines with many existing routing mechanisms, or run alone as a topology building mechanism. It does not consider the influence of PODA on packet loss rate in the network as the performance of the routing protocols is dramatically affected by a more real physical layer [15]. The energy balancing problems of non uniformly distributed nodes is not considered. And also the energy balancing problem when the sink node is not at the center of the network is not considered.

Energy-efficient routing algorithm to prolong lifetime (ERAPL) [20]

Energy-efficient routing algorithm to prolong lifetime (ERAPL) of WSN has a data gathering sequence (DGS) to eliminate mutual transmission and loop transmission among the nodes. Each node proportionally forwards traffic to its neighboring node. The objective function of the mathematical programming model incorporates minimal remaining energy and total energy consumption. The optimal solutions are obtained using genetic algorithms (GAs) having compressed chromosome coding scheme. The ERAPL is able to achieve better network lifetime with the help of GA. It is done by choosing a suitable group of parameters. It performs better than LET, the PEDAP, and the PEDAP-PA while expending energy efficiently.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [21]

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is a near optimal for this data gathering application in sensor networks. It forms a chain among the sensor nodes for each node to receive and transmit to its close neighbor. This forms the key idea in PEGASIS. The gathered data moves from node to node and get fused. The designated node eventually transmits to the BS. The average energy spent by each node per round is reduced as the nodes take turns transmitting to the BS. The total length is minimized by building a chain similar to the traveling salesman problem. It is intractable. The life time and quality of the network can be increased by the distribution of the energy load among the nodes.

Energy Efficient Interest based Reliable Data Aggregation protocol (EIRDA)[22]

Energy Efficient Interest based Reliable Data Aggregation (EIRDA) protocol delivers the data to the sink effectively. The static clustering scheme is considered for the uniform distribution of sensor nodes (SNs) in each cluster. It is based on the interest generated by Base station (BS). The Sensor Nodes (SN) and the Cluster head (CH) match the interest of BS. The same interest id is generated by the SNs and the data is transmitted to the CH. The reliable SN's is selected from among the interested SN's by the CH. The aggregation function is applied to the data received from the SNs within the cluster. The aggregated data is delivered to the BS. The concept of Functional Reputation provides reliability in the protocol. Its implementation is done using Beta-distribution function. The energy spent in the setup phase of the protocol indicates the overall impact of all measures taken for the protocol implementation at each phase. Energy efficiency will be provided by the multi-hop variation in steady phase.

3.2. Mobile Element Based Data Collection

Tinybee: Data Gathering System [23]

Tinybee: Data gathering system gathers data from deployed sensors in a sensing field. It uses mobile agents called as TinyBees. A moving server is used to dispatch TinyBees. It collects the data while the server keeps moving around sensor nodes. The Tinybee collects the data and come back to the server with aggregated data. An effective and intelligent gathering mechanism is focused by the system. When compared to the traditional server/client-based model, the TinyBee-based model is both time efficient and energy efficient.

Mobile Data Gathering With SDMA [24]

Mobile data gathering with SDMA (MDG-SDMA) involves a joint design of mobility and SDMA technique. The data uploading time and moving time constitutes the total time of a data gathering tour. Here it is assumed that all the sensors are static .When the data in the field are collected, the sensor nodes turn to the sleep mode for power saving. Hence the total time of a data gathering tour is minimized. The SenCar visits some specific locations for more sensors to use SDMA to make concurrent data uploading. Hence the data uploading time is shortened to enjoy the effect of SDMA. It may lead to the prolongation of the moving path. The tradeoff between the shortest moving path and full utilization of SDMA is done using the optimal solution. The major contribution of the proposed work is:

1) Here a joint design of the mobility and SDMA technique is introduced gather data in WSNs and it can be abstracted as the MDGSDMA problem.
2) the MDG-SDMA problem is formulated into an integer program (IP) and its NP-hardness is proved.
3) the MDG-SDMA problem is addressed through three newly proposed heuristic algorithms.
4) The proposed algorithms reduces the total time of a data gathering tour in a densely-deployed sensor network compared to the non- SDMA algorithm

In[25] a cost minimization problem constrained by the channel capacity, the minimum amount of data gathered from each sensor and the bound of total sojourn time at all anchor points is formulated to optimize the performance of mobile data gathering. At a particular anchor point, the cost of a sensor is the function of the data amount a sensor can upload to the mobile collector during its sojourn time at the anchor point. The global optimization problem is decomposed into two sub problems in order to provide an efficient and distributed algorithm. It is solved by each sensor and the mobile collector, respectively. The decomposition is characterized as a pricing mechanism. Here based on the shadow prices of different anchor points, each sensor independently adjusts its payment for the data uploading opportunity to the mobile collector. The two sub problems are solved jointly by an efficient algorithm. The proposed algorithm achieves the optimal data control for each sensor and the optimal sojourn time allocation for the mobile collector. Hence the overall network cost minimized

Enhanced Environmental Energy-Harvesting Framework (EEHF) [26]

Enhanced Environmental Energy-Harvesting Framework (EEHF) was proposed for the maximization of the lifetime of an environmental energy based WSN. It uses the following two methods: an enhanced environmental energy-harvesting framework (E-EEHF) for more accurate estimation than EEHF and a clustering method. It is optimized for environmental energy based WSNs. The estimation intervals are changed by E-EEHF to achieve more accurate estimation than EEHF. A cluster-based routing protocol for data gathering is used as the optimized data-gathering scheme under the conditions of use in an environmental energy-based WSN. The data gathering scheme is optimized for the environmental energy based sensor network and the environmental energy harvesting framework for prolongation of the network lifetime in the environmental energy based sensor network, hence accurate power estimation is enabled.

In [27] the proposed MULE architecture is a three-tiered design to exploit the mobility for energy efficient non real time data collection in sparse sensor networks as an alternative to forming an ad-hoc network. The main idea is the exploitation of the presence of mobile nodes in the environment. It is used as forwarding agents. The network lifetime is extended by the minimization of the communication responsibility of the resource-constrained sensors. It presents a analytical model based queuing theory and incorporates many detailed aspects such as different MULE mobility models, radio characteristics etc. When compared with the traditional ad-hoc network approach, the MULEs achieve energy savings up to two orders of magnitude. The main draw back is more work has to be done to understand the cost effectiveness of the approach. Many issues like reliability and MULE-to-MULE communication, issues surrounding naming, network layer, and end-to-end connectivity needed to be addressed.

In [28], the data gathering issues in a spatially separated wireless sensor network are considered. Several isolated sub networks are formed by the sensor nodes which are far away from each other. Data collection is done by the mobile mules by traversing through sub networks. Energy constrained Mule Traveling Salesman Problem (EM-TSP) is a new problem formulated for addressing the issues of data collection latency and network lifetime simultaneously. It finds mules' traversal paths to visit each subnetwork in at least one landing port. It causes the bounding on the energy consumption of sensors and also the minimization of the traversal path lengths of mules. EM-TSP can be projected as the generalization of the classical traveling salesman problem. Several heuristics to solve EM-TSP is proposed based on some interesting geometrical properties. The proposed solution is able to provide an efficient solution to EM-TSP in order to balance between data collection latency and network lifetime.

In [29], the possibility of a WSN becoming spatially separated into multiple subnetworks is considered. The mobile mule visit to subnetworks for collecting the sensing data in an efficient way is discussed. Sometimes the WSNs are separated naturally by the physical constraints, so the possibility of having isolated subnetworks is inevitable and more cost-effective. It is necessary to have coordination between spatially separated subnetworks. ne of the fundamental issue in WSN is the data gathering. The latency of the mule to travel between subnetworks and the latency for uploading data from each subnetwork constitutes to the data gathering latency. Hence the problem of minimization of the path length traversed by the mobile mule arises. The minimization of the path length reflects the data gathering latency and the energy consumption of the mule. It is the generalization of the traveling salesman problem and is NP-complete. Some heuristics are proposed on the basis of the geometrical properties of node deployment. The path length is decreased gradually.

In [30], a low-latency and reliable mobile data gathering solution for delay-sensitive applications for WSNs is proposed. The challenge is the alleviation of the high traffic load which results in bottleneck at the sink's vicinity due to the static approaches. The mobile data collectors (MDCs) broadcast beacons periodically. It is employed by the proposed MDC/PEQ protocol. On receiving the beacon the sensor node joins the MDC's cluster. The routing information of the nodes is updated to relay data packets to the corresponding MDC. The route re-configuration (handoff) is done by the sensor nodes using the signal strength of the beacon. It is simple and efficient. The exchange of messages is done locally within the nodes neighbors. Hence the overhead is minimized. The nodes neighbor keeps the record of the exchanged messages locally and minimizes the overhead. The packet delivery delay is reduced and reliability is increased with little or no overhead. It is done by reducing the number of hops a data packet has to traverse. The main drawback is that haven't considered the optimization of protocol parameters such as the beacon interval, the reception threshold, and the transmission range. The protocol doesn't support the disconnected or partitioned wireless sensor network.

In [31] a novel cluster-based algorithm is presented. It finds the efficient tours for mobile elements used for data collection in WSN. The proposed new algorithm that alternates between these phases and iteratively improves the outcome of each phase, based on the result of the other. As a result the network lifetime is increased significantly. The further maximization of the network lifetime can be done taking into account the nodes residual energy for the establishment of the tours which is not considered in this work. The heuristics of the proposed algorithm is modified in a straight forward manner in order to cope with unexpected delays in the network. It also allows the mobile element to pause and wait at nodes along the tour till the overall deadline constraints are met. The proposed algorithm does not consider the heterogeneous communication capabilities of the nodes and how to deal with it in the network.

Distributed Intelligent Data-Gathering Algorithm (DIDGA)[32]

The intelligent mobile data collector is used to collect data for the improvement of the networking facilities in the system. An efficient energy-aware distributed intelligent data-gathering algorithm (DIDGA) is proposed to improve the efficiency of data collection. It plans the data-gathering path for the mobile collector in WSNs. The high energy expenditure in Multihop routings is reduced by the DIDGA. It also increases the efficiency of the mobile collector to gather data. The mobile collector gathers the sensed data from nodes and divides the whole network into certain MCDS for minimizing it. It is done by the reducing in the number of hops in the network. The path formation optimized algorithm (PFOA) is proposed that combines ant colony algorithm and evolutionary algorithm for satisfying the time-limited constraints. The average hop counts, average data gathering time is decreased by the DIDGA. It also improves the event detection ratio, saves energy consumption of sensor nodes, and greatly extends the network lifetime. The required processing power not available in standalone sensor nodes can be provided collaborative in-network processing. It is can be done as a future work. Here the reliable links are chosen by the communication scheduling and balances the communication loads among the cluster nodes. It increases the communication reliability and the network lifetime.

In [33], Data mules traverse the sensed field along parallel straight lines for gathering the data from sensors. Data mules are the collection of a number of mobile collectors. Practically, the data mules cannot always move along the straight lines as some obstacles or boundaries may block their moving paths. The performance and the cost of the data mule scheme are based on the number of data mules and the distribution of sensors. If the movement of data mules are only along a straight line data mules may not cover all the sensors in the network incase only a small number of data mules are available and not all sensors are connected. The worst-case delay and time-limited data for entire data gathering is another drawback of the existing mobile data-gathering scheme as they do not consider it. It causes buffer overflow and delay in the agents. It also reduces the reliability of data collection.

Partition Based Scheduling (PBS) algorithm [34]

A Partition Based Scheduling (PBS) algorithm tackles the problem by dividing it into two sub-problems: Partitioning and Scheduling. At first the portioning of all nodes into several groups are done with respect to their data generation rate and location. In the scheduling algorithm, node visiting schedules are created for the ME inside a single group by reducing the overhead of moving back and forth across far-away nodes. At last, the entire Mobile Element path is generated by concatenating the scheduling solutions of the groups. Hence, every node can visit at adequate frequencies and buffer overflow can be prevented. The work does not consider the investigation of methods to use more than one mobile element for data collection. It also does not consider the needs to cater the urgent real-time communication events.

4. COMPARISON OF DATA GATHERING PROTOCOLS

Following tables gives merits and demerits of existing data gathering protocols in wireless sensor network.

Table 1. Comparison of Exiting Data Gathering Protocols

Name of the algorithm	Approach	Objective	Metrics	Drawbacks
Distributed Data Aggregation Protocol (DDAP)[1]	Static	Energy Power	Packet transmission, Average path length	The probability of being an aggregate node cannot be set adaptively.
Hybrid Clustering Based Data Aggregation Scheme[17]	Static	Energy Reliability	Average energy consumption per node, Data packet transmission success ratio, Average aggregation count per event	Large amounts of overheads
Optimal routing and data aggregation scheme[18]	Static	Energy, Network lifetime.	Aggregated data Rate.	It does not consider the data aggregation of multiple sink nodes and for nodes with sleeping mode.
Power-graded data gathering (PODA) [19]	Static	Energy, Network lifetime.	Average lifetime of the nodes, Distance	Packet loss rate, Energy balancing problem are not considered.
Energy-efficient routing algorithm to prolong lifetime (ERAPL) [20]	Static	Energy, Network lifetime.		Overhead
Power-Efficient GAthering in Sensor Information Systems (PEGASIS) [21]	Static	Energy	Node Death, Number of rounds	Induces lots of delay in data transmissions to the BS
Energy Efficient Interest based Reliable Data Aggregation protocol (EIRDA)[22]	Static	Energy, Reliability	Energy Consumption, No of rounds.	
Tinybee: Data Gathering System [23]	Mobile	Energy	Residual energy, Execution time, Size of the tinybee, No of nodes, Energy consumption ratio	Buffer overflow, Visiting schedule.
Mobile Data Gathering With SDMA [24]	Mobile	Power, Minimization of total time for data gathering		Buffer overflow, Visiting schedule
A Cost Minimization Algorithm for Mobile Data Gathering in Wireless Sensor Networks[25]	Mobile	Cost	Total sojourn time, Number of sensors	Buffer overflow, Visiting schedule.
Enhanced Environmental Energy-Harvesting Framework (EEHF) [26]	Mobile	Power, Network lifetime, Energy	Alive rate, Time	The proposed scheme is not implemented in the sensor node
Exploiting Mobility For Energy Efficient Data Collection[27]	Mobile	Energy, Network lifetime,	MULEs per hour, average sensor buffer occupancy, data success ratio (DSR), Latency	Cost effectiveness, Reliability, end to-end connectivity, MULE-to-MULE communication, Buffer overflow.
Energy-Conserving Data Gathering by Mobile Mules in a Spatially Separated Wireless Sensor Network[28]	Mobile	Energy Data collection latency, Network lifetime	Number of nodes, Number of subnetworks, Path length, Minimum remaining energy	Buffer overflow
Data Gathering by Mobile Mules in a Spatially Separated	Mobile	Energy, Data gathering latency	Path Length, Number of nodes, Average	Buffer overflow

Wireless Sensor Network[29]			number of subnetworks, traversal length of the Mule, Fail Probability	
Mobile data collector strategy for delay-sensitive applications over wireless sensor networks[30]	Mobile	Reliabilty, Low-latency,	Number of Mobile Nodes, Average Energy Dissipation per node, Average route changes per beacon, Number of hops, percentage of packets received, Average packet delivery ratio, Average packet delay.	Optimization of the beacon interval, The reception threshold, and the transmission range, Does not support disconnected or partitioned wireless sensor network.
Energy-Efficient Data Gathering with Tour Length-Constrained Mobile Elements in Wireless Sensor Networks[31]	Mobile	Network lifetime, Energy.	Network lifetime, Number of nodes, Routing trees size,	Maximization of network, Heterogeneous communication capabilities are not dealt, No measures to cope with unexpected delay.
Distributed Intelligent Data-Gathering Algorithm (DIDGA)[32]	Mobile	Energy, Network lifetime,	Path length, Average hop counts, Average data gathering time, Remaining energy, Event detection ratio.	Reliability, Network lifetime, Power.
Multiple Controlled Mobile Elements (Data Mules) for Data Collection in Sensor Networks[33]	Mobile	Load balancing	Data Mule ID	Buffer overflow and delay, Reliability of data collection.
Partition Based Scheduling (PBS) algorithm[34]	Mobile	High predictability, Minimization of data loss rate, Visiting scheduling.	Data loss rate, Minimum speed	It does not consider more than one element to for data collection and to cater to the needs of urgent real-time communication events.

5. CONCLUSION

This paper includes survey based on the data gathering techniques in the WSN as it occupies a significant place in the WSN. It is one of the important applications of WSN. This paper elaborates on classification of the data gathering techniques into two category namely static and mobile. It is done on the basis of mobility of the nodes. In this survey, most of the static element based data gathering techniques in the WSN considers energy, reliability and network lifetime for the efficient data gathering. Most of the mobile element based data gathering considers energy, data collection latency, Network life time, reliability, cost, load balancing etc for the efficient data gathering. But in data gathering techniques the metrics like visiting schedule and the buffer overflow are not much considered.

ACKNOWLEDGMENT

The Author wish to thanks VGST, Govt. of Karnataka for awarding Grant under K-Fist (Level-1) for the year 2012-13. The Authors are also thankful to The Management and The Principal of NIE, Mysore for their Encouragement in this regard.

REFERENCES

[1] Dorottya Vass, Attila Vidacs, "Distributed Data Aggregation with Geographical Routing in Wireless Sensor Networks", IEEE Int. Conf., Hangery, 2007, pp .68-77.

[2] Chong Liu, Kui Wu,Jian Pei, "A Dynamic Clustering and Scheduling Approach to Energy Saving in Data Collection from Wireless Sensor Networks", 2nd *Annu*. IEEE *Conf*, Sept 2005, pp. 374 -385.

[3] Natarajan Meghanathan, Sugam K. Sharma, Gordon W. Skelton, "On Energy Efficient Data Dissemination In Wireless Sensor Networks Using Mobile Sinks", Journal Of Theoretical And Applied Information Technology, 2010,pp.79-91

[4] Prem Prakash Jayaraman, Arkady Zaslavsky, Jerker Delsing, "Cost Efficient Data Collection of Sensory Originated Data using Context-Aware Mobile Devices", 27-30 April 2008.

[5] Tao Cui, Lijun Chen, Tracey Ho, Steven H. Low, and Lachlan L. H. Andrew, "Opportunistic Source Coding for Data Gathering in Wireless Sensor Networks",2007.

[6] Masaaki Takahashi, Bin Tang, and Neeraj Jaggi, "Energy-Efficient Data Preservation in Intermittently Connected Sensor Networks", Third International Workshop on Wireless Sensor, Actuator, Robot Networks, 2011, pp.596-601.

[7] Feng Wang And Jiangchuan Liu, "Networked Wireless Sensor Data Collection: Issues, Challenges, And Approaches", IEEE Communications Surveys & Tutorials For Possible Publication, 2011.

[8] Deepak Puthal, Bibhudatta Sahoo, Suraj Sharma, "Dynamic Model for Efficient Data Collection in Wireless Sensor Networks with Mobile Sink", IJCST Vol. 3, No.1, Jan. - March 2012.

[9] Yang Yu, Bhaskar Krishnamachari and Viktor K. Prasanna, "Energy-Latency Tradeoffs for Data Gathering in Wireless Sensor Networks",

[10] Christelle Caillouet, Xu Li, and Tahiry Razafindralambo, "A Multi-objective Approach for Data Collection in Wireless Sensor Networks",2011.

[11] Mujdat Soyturk, Halil Cicibas and Omer Unal, "Real Time Data Acquisition in Wireless Sensor Networks", Turkey, 2010,ch.4.

[12] Mingming Lu and Jie Wu, "Utility-Based Data-Gathering in Wireless Sensor Networks with Unstable Links" in Proceedings of the 9th international conference on Distributed computing and networking, Springer-Verlag Berlin, Heidelberg ,2008,pp.13-24.

[13] K.Ramanan and E.Baburaj, "Data Gathering Algorithms For Wireless Sensor Networks: A Survey", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.1, No.4, December 2010, pp.102-114.

[14] Mario Di Francesco, Sajal K. Das, Giuseppe Anastasi "Data Collection in Wireless Sensor Networks with Mobile Elements: A Survey", Journal on ACM Transactions on Sensor Networks (TOSN), August 2011, Vol. 8, Issue 1, , Article No. 7.

[15] Ramesh Rajagopalan and Pramod K. Varshney, "Data aggregation techniques in sensor networks: A survey", Communications Surveys & Tutorials, IEEE,2006, vol. 8, pp.48 - 66.

[16] Longjiang Guo, Raheem Beyah and Yingshu Li, "SMITE: A Stochastic Compressive Data Collection Protocol for Mobile Wireless Sensor Networks", IEEE 2011.

[17] Woo-Sung Jung, Keun-Woo Lim, Young-Bae Ko, Sang-Joon Park, "A Hybrid Approach for Clustering-based Data Aggregation in Wireless Sensor Networks", Third International Conference, Feb. 2009, pp. 112-117.

[18] Cunqing Hua and Tak-Shing Peter Yum, "Optimal Routing and Data Aggregation for Maximizing Lifetime of Wireless Sensor Networks", IEEE/ACM Transactions On Networking, Vol. 16, No. 4, August 2008,pp.892-903.

[19] Bi Yan-Zhong, Yan Ting-Xin, Sun Li-Min1,Wu Zhi-Mei, "A Power Graded Data Gathering Mechanism for Wireless Sensor Networks", ACTA AUTOMATICA SINICA, Vol. 32, No. 6, November, 2006,pp.881-891.

[20] Yi-hua Zhu, Wan-deng Wu, Jian Pan, Yi-ping Tang, "An energy-efficient data gathering algorithm to prolong lifetime of wireless sensor networks", Computer Communications 33, 2010,pp. 639–647.

[21] Stephanie Lmdsey and Cauligi S. Raghavendra, "PEGASIS: Power-Efficient GAthering in Sensor Information Systems", IEEE, 2001,pp.1125-1130.

[22] Hemant Sethi, Devendra Prasad,R. B. Patel, "EIRDA: An Energy Efficient Interest based Reliable Data Aggregation Protocol for Wireless Sensor Networks", International Journal of Computer Applications (0975 – 8887) Vol. 22,No.7, May 2011,pp.21-25.

[23] Kaoru Ota, Mianxiong Dong, Xiaolin Li, "TinyBee: Mobile-Agent-Based Data Gathering System in Wireless Sensor Networks", Jully 2009, *Int. Conf.*, pp 24-31.

[24] Miao Zhao, Ming Ma and Yuanyuan Yang, "Mobile Data Gathering with Space-Division Multiple Access in Wireless Sensor Networks", IEEE INFOCOM, 27th Conf on Computer Communications, 2008, pp. 1283-1291.

[25] Miao Zhao, Dawei Gong and Yuanyuan Yang, "A Cost Minimization Algorithm for Mobile Data Gathering in Wireless Sensor Networks", IEEE, 2010, pp. 322-331.

[26] Kazuhiko Kinoshita, Takahisa Okazaki, Hideki Tode And Koso Murakami, "A Data Gathering Scheme for Environmental Energy-based Wireless Sensor Networks", IEEE CCNC 2008, pp.719-723.

[27] Sushant Jain,Rahul C. Shah,Waylon Brunette, Gaetano Borriello, Sumit Roy, "Exploiting Mobility for Energy Efficient Data Collection in Wireless Sensor Networks", Mobile Networks and Applications 11, 2006, pp. 327–339.

[28] Fang-Jing Wu and Yu-Chee Tseng, "Energy-Conserving Data Gathering by Mobile Mules in Spatially Separated Wireless Sensor Network", Wireless Communications And Mobile Computing, 2010, pp. 1-18.

[29] Fang-Jing Wu, Chi-Fu Huang, and Yu-Chee Tseng, "Data Gathering by Mobile Mules in a Spatially Separated Wireless Sensor Network", in *Proc.*9th *Intr Conf,* IEEE Computer Society Washington, USA,2009, pp.293 -298.

[30] Richard W.N. Pazzi, Azzedine Boukerche, "Mobile data collector strategy for delay-sensitive applications over wireless sensor networks", Journal Computer Communications March 2008, Vol.31,pp. 1028–1039.

[31] Khaled Almi'ani, Anastasios Viglas, Lavy Libman, "Energy-Efficient Data Gathering with our Length-Constrained Mobile Elements in Wireless Sensor Networks",IEEE 35th *Conf.* on Local Computer Networks, IEEE Computer Society Washington, USA ,2010 , pp.598-605.

[32] Rongbo Zhu, Yingying Qin, and JiangqingWang, "Energy-Aware Distributed Intelligent Data Gathering Algorithm in Wireless Sensor Networks", International Journal of Distributed Sensor Networks, 2011,pp 13.

[33] David Jea, Arun Somasundara, Mani Srivastava, "Multiple Controlled Mobile Elements (Data Mules) for Data Collection in Sensor Networks". Ist IEEE *Int.Conf.* on Distributed Computing in Sensor Systems, Springer-Verlag Berlin, Heidelberg ,2005, pp. 244-257.

[34] Yaoyao Gu, Doruk Bozdag˘, Eylem Ekici, Fu¨sun O¨ zgu¨ner, Chang-Gun Lee, "Partitioning Based Mobile Element Scheduling in Wireless Sensor Networks", 2nd *Annu,* IEEE Society *Conf. Sept* 2005, pp. 386-395.